Claims

1. An improved p-type gallium nitride-based semiconductor device comprising:

a device structure that includes at least one p-type Group III nitride layer that includes some gallium;

a first silicon dioxide layer on said p-type layer;

a layer of a Group II metal source composition on said first SiO_2layer; and

a second SiO_2 layer on said Group II metal source composition layer.

2. A semiconductor device according to Claim 1 wherein said device structure comprises:

a conductive silicon carbide substrate;

a conductive buffer layer on said silicon carbide substrate for providing a crystal transition between said substrate and said Group III nitride portions of said device; and

an n-type Group III nitride layer on said buffer layer.

3. A device according to Claim 1 wherein said first silicon dioxide layer is thick enough to create vacancies to a depth in said p-type layer that encourages atoms of said Group II metal to diffuse thereinto while still permitting diffusion from said Group II metal source composition through said first SiO_2 layer and into said p-type layer.

4. A device according to Claim 1 wherein:

said first SiO_2 layer is about 1000 Å thick;

said Group II metal source composition layer is about 1000 Å thick; and

said second SiO_2 layer is about 2500 Å thick.

5. A device according to Claim 1 wherein said Group III nitride comprises GaN and said source composition layer is selected from the group consisting of magnesium and zinc.

6. A method of activating the p-type layers and passivating a Group III nitride device, the method comprising: thermally annealing the structure according to Claim 1.

7. A device structure according to Claim1 wherein said substrate is n-type and has a carrier concentration of between about 1 X 10^{16} cm^{-3} and about 1 X 10^{19} cm^{-3} .

8. A device according to Claim 1 wherein said Group II metal source composition layer comprises a Group II metal-containing compound.

9. A device according to Claim 8 wherein said compound is selected from the group consisting of magnesium nitride and zinc phosphide.

10. A device according to Claim 1 wherein said p-type gallium nitride layer has the formula $Ga_xAl_yIn_{1-x-y}$ where $0 < x \leq 1$ and $0 \leq y \leq 1$.

11. A device according to Claim 1 comprising a plurality of silicon dioxide portions on said p-type Group III nitride layer, with a respective portion of said source composition on each said silicon dioxide portion.

12. A device according to Claim 11 wherein said second silicon dioxide layer is limited to said source composition portions.

13. A device according to Claim 11 wherein said second silicon dioxide portion covers said source composition portions and portions of said p-type Group III nitride layer.

14. An improved p-type gallium nitride-based device comprising:

a conductive silicon carbide substrate;

a conductive buffer layer on said silicon carbide substrate for providing a crystal transition between said substrate and said GaN portions of said device;

an n-type GaN layer on said buffer layer;

a p-type GaN layer on said n-type layer;

a first silicon dioxide layer on said p-type layer;

a magnesium layer on said first SiO_2 layer for supplying p-type dopant to said p-type layer; and

a second SiO_2layer on said Mg layer for passivating said device;

said first silicon dioxide layer being thick enough to create vacancies to a required depth in said p-GaN layer when said device is heated to temperatures between about 750° and 950° C while still permitting diffusion from the magnesium layer through said first SiO_2 layer and into the p-GaN layer at such temperatures.

15. A device according to Claim 14 wherein said substrate is n-type.

16. A device according to Claim 14 wherein said buffer is selected from the group consisting of: graded layers of Group III nitrides, homogeneous layers of Group III nitrides, heterogeneous layers of Group III nitrides and combinations thereof.

17. A device according to Claim 14 wherein said n-type layer comprises $Al_xIn_yGa_{1-x-y}N$ where $0 \leq x \leq 1$ and $0 \leq y \leq 1$

18. A device according to Claim 14 wherein said p-type layer comprises $Ga_xAl_yIn_{1-x-y}$ where $0 < x \leq 1$ and $0 \leq y \leq 1$.

19. A method of activating the p-type layers and passivating a Group III nitride device, the method comprising thermally annealing a structure that includes at least the following elements:

at least one p-type Group III nitride layer that includes some gallium;

a first silicon dioxide layer on said p-type layer;

a layer of a Group II metal source composition on said first SiO_2 layer; and

a second SiO_2 layer on said source composition layer layer.

20. A method according to Claim 19 comprising annealing the structure for a time sufficient for the structure to reach at temperature of between about 750° and 950° C.

21. A method according to Claim 20 comprising annealing the structure to reach a temperature of between about 850° and 875° C.

22. A method according to Claim 20 comprising annealing the structure for about 5 minutes.

23. A method of increasing the activation of a p-type Group III nitride layer that includes some GaN, the method comprising:

forming a first layer of SiO_2 on the p-type layer;

forming a layer of a Group II metal source composition;

forming a second layer of SiO_2 on the metal layer; and

annealing the structure to diffuse the metal from the metal layer into the p-type gallium-containing layer and to activate metal atoms in the p-type layer.

24. A method according to Claim 23 wherein the step of forming the first SiO_2 layer comprises forming the SiO_2 layer to a thickness sufficient to create gallium vacancies to a required depth in said p-type layer during the annealing step while still permitting magnesium to diffuse from the metal layer through said first SiO_2 layer and into activated positions in the p-type layer.

25. A method according to Claim 23 comprising annealing the structure at a temperature and for a time sufficient to provide an activated p-type layer of at least about 1E17.

26. A method according to Claim 25 comprising forming the SiO_2 layer to a thickness of about 1000 Å and annealing the structure for a time sufficient for the structure to reach at temperature of between about 750° and 950° C.

27. A method according to Claim 26 comprising annealing the structure to reach a temperature of between about 850° and 875° C.

28. A method according to Claim 26 comprising annealing the structure for about 5 minutes.

29. A method according to Claim 23 comprising increasing the activation of a p-type GaN layer.

30. A method according to Claim 23 wherein the step of forming the source composition layer comprises forming a layer of a metal selected from the group consisting of magnesium and zinc on the first SiO_2 layer.

31. A method according to Claim 23 wherein the step of forming the source composition layer comprises forming a layer of a compound containing a Group II metal on the first SiO_2 layer.

32. A method according to Claim 31 comprising forming a layer of selected from the group consisting of magnesium nitride and zinc phosphide.

33. A method according to Claim 23 and further comprising
removing the first and second SiO_2 layers and the metal source composition layer and depositing a silicon nitride cap on the remaining structure.

34. A method according to Claim 33 wherein the step of removing the layers comprises etching the layers.

35. A method of creating a p-type layer from a nominally n-type GaN layer, the method comprising:

forming a first layer of SiO_2 on the nominally n-type layer;

forming a layer of magnesium on the first SiO_2 layer;

forming a second layer of SiO_2 on the magnesium layer; and

annealing the structure to diffuse magnesium from the magnesium layer into the nominally n-type GaN layer and to activate sufficient magnesium in the layer to produce p-type characteristics.

36. A method according to Claim 35 comprising annealing the structure for a time sufficient for the structure to reach a temperature of between about 750° and 950° C.

37. A method according to Claim 36 comprising annealing the structure to reach a temperature of between about 850° and 875° C.

38. A method according to Claim 36 comprising annealing the structure for about 5 minutes.

39. A method of creating a p-type layer from a nominal n-type GaN layer, the method comprising:

annealing the GaN layer in the presence of an adjacent SiO_2 layer, a layer of a Group II metal source composition on the adjacent SiO_2 layer and a second SiO_2 layer on the metal layer;

until the GaN layer demonstrates p-type characteristics.

40. A method according to Claim 39 comprising annealing a GaN layer having a n-type carrier concentration of 5E16 or less

41. A method according to Claim 39 comprising annealing the GaN layer until the GaN layer demonstrates a p-type carrier concentration of at least about 1E17.

42. A method according to Claim 39 comprising annealing the structure for a time sufficient for the structure to reach a temperature of between about 750° and 950° C.

43. A method according to Claim 42 comprising annealing the structure to reach a temperature of between about 850° and 875° C.

44. A method according to Claim 42 comprising annealing the structure for about 5 minutes.